AIR WAR COLLEGE

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COGNITION 2035: SURVIVING A COMPLEX ENVIRONMENT THROUGH UNPRECEDENTED INTELLIGENCE

by

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Biography

Lieutenant Colonel Michael Finn II is currently a student at Air War College. In addition to his current enrollment in Senior Developmental Education at the Air War College, his professional military education includes Squadron Officers' School (1996), Air Force Intern Program (1997- 1999), and Intermediate Developmental Education at the Air Force Institute of Technology (2003-2004). Colonel Finn has an undergraduate degree in Mathematics from the University of Mississippi (1991), a Master of Art degree in Organizational Leadership from George Washington University (1999), and a Master of Science degree in Systems Engineering from the Air Force Institute of Technology (2004). Colonel Finn has over 17 years of active duty service as a Communications and Information Officer. He has had experience across the entire spectrum of communications and cyber operations. Colonel Finn's most recent assignment was as Commander, 509th Communications Squadron, Whiteman Air Force Base, Missouri, where he ensured communication, airfield, and security systems were fully operational in support of the nation's two billion dollar B-2 Stealth Bomber fleet. Colonel Finn also recently deployed to Kandahar Airfield, Afghanistan in support of Operation Enduring Freedom. As the Deputy Commander for the 451st Air Expeditionary Group, Colonel Finn ensured Air Force rotary-wing Combat Search and Rescue, as well as, Reaper and Predator Unmanned Aerial Vehicle operations were supported for the entire Afghanistan Area of Responsibility.

Chapter 1

Introduction

> <u>cognition</u>: A term referring to the mental processes involved in gaining knowledge and comprehension, including thinking, knowing, remembering, judging, and problem solving. These are higher-level functions of the brain and encompass language, imagination, perception, and planning.[1]

> A law of acceleration, definite and constant as any law of mechanics, cannot be supposed to relax its energy to suit the convenience of man…Fifty years ago, science took for granted that the rate of acceleration could not last.[2]
>
> -- Henry Adams, 1909

In an environment of accelerating complexity, current cognitive powers are insufficient to provide adequate understanding or anticipation of the environment. By 2035, advances in nano-scale, biological, and information technologies will drive cognition toward unprecedented capabilities in Artificial Intelligence (AI) and Enhanced Human Intelligence (EHI). These capabilities will have a dramatic effect on all levels of the Air Force and can be applied across the full spectrum of combat and support operations.

The importance of knowledge and Knowledge Based Operations has long been recognized within the Department of Defense and the United States Air Force. All decisions are based on the application of knowledge. Cognition is the transformation of information into knowledge, as well as, the application of that knowledge to the situation or environment. Cognition is required to understand the current environment and predict future conditions or events. Intelligence is a limiting factor of cognition. Intelligence determines the amount of information that can be ingested, the speed at which it can be processed, and how effectively it can be communicated. Rapid change

precipitates an exponential increase in the volume and complexity of information. Humans are increasingly challenged to maintain cognitive balance in a rapidly changing environment because of limits on current biological intelligence.

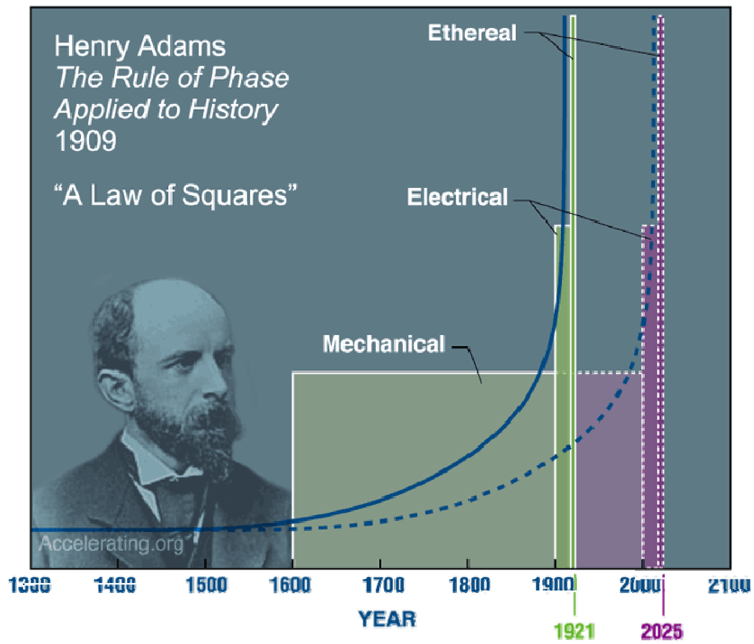

Figure 1 - Henry Adams Acceleration Curve 1909[3]

The phenomenon of accelerating change, driven primarily by technology, creates an exponential curve of increasing complexity over time. The 'curve' of accelerating change creates an increasing gap between human linear prediction and the exponential changes in the environment. The idea of the curve of accelerating change is not new. Henry Adams, grandson of President John Quincy Adams, conceived of inevitable acceleration punctuated by a global "phase change" as early as 1909. Adams predicted that the phase change would change the relationship between technology and humanity sometime between 1921 and 2025 (Figure 1).[4] This phase change is referred to as the

‘Singularity’ by contemporary futurists. Ray Kurzweil, a leading ‘Singularitarian’, defines the Singularity as “a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed.” [5]

Figure 2 – Cognitive Reality Curve

The cognition required to compensate for the “intelligence gap” (Figure 2) created by increasing change and complexity must be met by engineered increases in intelligence both in the domain of the human mind through EHI and in the domain of cyberspace through AI. Many of the technologies required for an “intelligence revolution” are in their infancy and bringing them to maturity faces technical and ethical challenges.

Nevertheless, the Air Force will need to bring these technologies to bear if it is to be effective in 2035. AI and EHI will have application across the full spectrum of warfare in all operating environments. Furthermore, these technologies will be essential for making long term force development decisions.

Notes

(Notes may appear in shortened form. For full details, see appropriate entry in the bibliography.)

[1] Cognition - What Is Cognition?, About.com. Retrieved October 23, 2008, http://psychology.about.com/od/cindex/g/def_cognition.htm

[2] Quoted in Smart, “Brief History of Intellectual Discussion of Accelerating Change.”

[3] Copied from Smart, “Brief History of Intellectual Discussion of Accelerating Change.”

[4] Smart, “Brief History of Intellectual Discussion of Accelerating Change.”

[5] Kurzweil, *The Singularity is Near.*

Chapter 2

Dangerous thinking: Linear predictions in a non-linear environment

> During the next 30 years, every aspect of human life ***will*** [emphasis in original] change at an unprecedented rate, throwing up new features, challenges and opportunities…Innovation is ***likely*** to continue at an unprecedented rate and there is ***likely*** to be a multiplicity of sources of innovation and production. Making predictions about how novel and emerging technologies would be exploited and applied ***will*** be difficult and imprecise. The rate of change, tempo and unpredictability of innovation and development ***will*** challenge decision-makers who ***will*** have to anticipate and respond to direct and indirect outcomes.[6]
>
> – UK MoD, Global Strategic Trends 2007-2036

Humans are poor at predicting future events. Humans make predictions by analogy to the past, so we tend to think of future events in terms of the past.[7] We link current events to past events and make a linear assumption about the future. The problem is that change is rarely linear. In fact, there is significant evidence that the global environment is changing at an accelerated rate. This accelerated rate of change exacerbates our ability to make even short term predictions. For example, Bill Gates and other technology leaders have observed that we tend to overestimate the impact of technology in the short-term (less than two years), but grossly underestimate technological impact in the long term (ten years).[8] As change continues to accelerate, so does complexity and the linear nature of human prediction will continue to get worse (Figure 2).

Our inability to make reliable predictions is rooted in the way we process complex problems. The brain is a massively parallel, distributed, and highly interactive system. It has about 100 billion neurons making approximately 100 trillion connections. "For problems…such as…pattern recognition, the human brain does a great job. For problems that require sequential thinking, the brain is mediocre."[9] Human cognitive abilities "come in clumps" (i.e., the abilities are systematically related into specialized regions and not distributed evenly across the brain). [10] The prefrontal cortex provides temporal organization and integration for higher cognitive operations, including human language and reasoning.[11] Unfortunately, human ability to process sequentially is incredibly slow due to the cerebral cortex (the portion of the brain responsible for logical and recursive thought) only having approximately 8 million neurons firing at only 200 calculations per second.[12]

Consider the game of chess, which is a closed system and, therefore, not highly complex. Assume that a player wants to play a perfect game, then he would have to compute all of the possible moves to ensure victory. If on average there are eight possible moves to consider for each turn, and each game lasts, on average, 30 turns then there are 8^{30} moves to consider to fully exhaust all of the move-countermove combinations. If the player were extraordinarily intelligent and able to analyze a billion board positions per second it would take 10^{18} seconds (40 billion years) to consider each move. Since the rules of play don't generally allow that much time, the player will have to settle for less than perfect play. In fact, most chess masters pre-

compute moves based on pattern recognition achieved through experience and the study of chess. The master can then use the brain's immense pattern-recognition capability to match the current board to a mental library of previously considered scenarios.

Given the difficulty of computing in a closed system, such as chess, it is easy to see that a complex environment with several variables is unlikely to be predictable by even the most intelligent humans. In a very complex environment, the immediate results of decisions will be difficult to predict. Anticipation of the second and third order effects will be impossible.

All indications are that complexity will continue to accelerate through 2035. Air Force personnel, at all levels, will be challenged to successfully operate in an increasingly complex environment. The Cyber domain will continue to become more powerful and ubiquitous. The improvements in infrastructure and computing power will generate an exponentially increasing amount of information. Superior cognitive power will be required to assimilate the torrent of information made available and convert the information into knowledge and then understanding, decision, and action (Figure 3). The potential of AI and EHI provides opportunity to dramatically improve cognitive power. This will allow for rapid, adaptive thinking that may approximate the exponential nature of change and allow better predictions of the future.

Figure 3 - BNI-Intelligence-Cognition Positive Feedback Loop[13]

Notes

[6] UK MOD DCDC, "*Global Strategic Trends*"

[7] Hawkins, *On Intelligence*.

[8] Bill Gates from his book *The Road Ahead,* quoted in Nancy Weil, IDG News Service, "The Quotable Bill Gates," *CIO.com (June 20, 2008)*, http://www.cio.com/article/405313/The_Quotable_Bill_Gates.

[9] Kurzweil, *Spiritual Machines*.

[10] Arbib, The Handbook of Brain Theory and Neural Networks, p. 40-42.

[11] Arbib, The Handbook of Brain Theory and Neural Networks, p. 37-39.

[12] Kurzweil, *Spiritual Machines*.

[13] Cyber model (relationship of Infrastructure, Computing Power, and Knowledge) derived from Air War College Cyber lecture (Hailes and Stein, 2008).

Chapter 3

Future intelligence – Technology behind enhanced cognition

There are at least two approaches to increasing the net cognitive ability available to decision-makers: Artificial Intelligence (AI) and Enhanced Human Intelligence (EHI). The convergence of bio-, nano-, and information-technologies will make possible stunning advances in AI and EHI. There is a wide spectrum of progress in bio-, nano-, and information-technologies that will combine to provide unique enhancement to each application of AI and EHI. The resulting superior cognitive capability may in-turn provide breakthroughs in the enabling bio-, nano-, and information-technologies, thus creating positive feedback loops and spin-offs for future bio-, nano-, and information-technologies and further acceleration AI and EHI capabilities (Figure 3). However, progress in bio-, nano-, and information-technologies and their application in AI and EHI come with risk and significant ethical considerations.

Artificial Intelligence

> Artificial Intelligence…that audacious effort to duplicate in an artifact what we humans consider to be our most important, our identifying property—our intelligence. – Pamela McCormick, *Machines Who Think*

The promise of Artificial Intelligence (AI) has been around since the advent of the computer. AI entities have pervaded our fictional literature and film. Iconic AIs include Asimov's robots, HAL in *2001: Space Odyssey*, the ship's computer on *Star Trek*, and *Star Wars'* C3PO, to name a few. The continuous pursuit of AI has been driven by the desire to model the natural

world, in particular the human mind, and empowered by computational theory. The brain of AI lies in mathematics and computational science and the heart has been the exponentially increasing computational power of computers (characterized by Moore's Law[14]), which has pumped life blood into the mostly embryonic AI applications.

AI research and development can be characterized by three branches. The first branch is a somewhat traditional rule-based method that is founded on computer algorithms and raw computational power. The goal is to execute tens of billions of serial instructions per second to approximate human intelligence. The second approach is a naturalistic effort to mathematically model the human brain and neurons. Neural networks exploit complexity theory to develop models of neurons in the form of nodes and links. Artificial Neural Networks (ANNs) provide a powerful technology for parallel, adaptive computation that better models the human brain.[15] Finally, the third common approach is genetic or evolutionary algorithms in which computer problem solving and learning is achieved through genetic associations followed by a Darwinian "survival of the fittest" approach to the derived solutions. The weakest solutions are removed and the surviving solution set is used to further refine the solution or determine new solutions.

Rule-based AI has evolved with computers and computational theory. In the 1930s, while the computer had just entered the electro-mechanical stage, Alan Turing developed an abstract tool to simulate the logic of computational procedures. The "Turing machine" was able to compute functions on natural

numbers that provided the first definitions of abstract computability. The 1940s and '50s introduced general purpose computers that were able to establish that the Turing functions were actually computable. The serial, rule-based approach of this time was promising since the number of calculations per second was expected to dramatically improve. However, the number of calculations was limited by computer memory and computation time. [16] Expert systems based on rule-based algorithms represent expert knowledge for a particular problem area as a set of rules and perform inferences when new data are entered. Today, these decision systems have overcome past limitations through the availability of ever-increasing memory and computational power. As computational power and affordability increase, these systems will become more viable especially when numerical confidence values can be established and problems can be solved through the serial application of explicit rules. [17]

During the period when rule-based AI seemed to stagnate, researchers sought to develop artificial neural networks that modeled the human brain. The 1960s introduced complexity theory and the ability to achieve pattern matching and classification on subsets of multidimensional vector spaces within constrained computer resources. [18] The development of universal approximators based on the advances in complexity theory led to recent developments in mathematical theory of feedforward networks. These networks permit multivariable functions without the "curse of dimensionality."[19] The advent of neural networks allows computation of more functions within a given time period when compared to traditional processing

models. Using real value weighting in the neural network has opened the possibility for infinite precision operations within the neural network and renewed complexity theory in pursuit of AI. [20] Neural networks can provide mechanisms for the formation of associations that model the properties of human intelligence, such as the invariance in which similar (but not exact) inputs yield similar responses.[21] Additionally, neural networks have provided advances in automatic tracking and guidance systems, visual recognition and motor control, and forecasting applications.[22]

Evolutionary and genetic algorithms are the relative newcomers to AI. These algorithms create a simulated environment in which 'creatures' or 'genomes' compete for survival. The contest for survival yields emergent solutions that are frequently not predictable. This approach has demonstrated success in financial analysis and is used by several investment fund managers. The real power of evolutionary algorithms is realized when coupled with one or more of the other AI paradigms.[23]

To date, none of these three approaches has delivered on the promise of consciousness, intuition, creativity, or sentience. Performance alone is insufficient to measure machine intelligence. Machines currently outperform humans on specialized tasks such as numerical calculations and weather modeling. However these machines don't understand mathematics or meteorology. According to Jeff Hawkins,

> Many people today believe that AI is alive and well and just waiting for enough computing power to deliver on its many promises. When computers have sufficient memory and processing power, the thinking goes, AI programmers will be able to make intelligent machines. I disagree. AI suffers from a fundamental

> flaw in that it fails to adequately address what intelligence is or what it means to understand something...Intelligence is measured by the capacity to remember and predict patterns from the outside world, including language, mathematics, physical properties of objects, and social situations. Your brain receives patterns from the outside world, stores them in memories, and makes predictions by combining what it has seen before and what is happening now.[24]

A blended approach to AI will most likely be required to reach some level of general human intelligence by 2035. Human cognitive processes have both symbolic processes for capturing explicit information and connectionist processes for synthesizing implicit information. The use of expert systems and neural networks together give the best opportunity for success in developing mature AI.[25]

By 2035, the convergence of bio-, nano-, and information-technologies will yield computational speed, memory capacity, and connectivity to approximate the computing capacity of a single human brain. It is not clear that machines will have achieved general intelligence by 2035. However, non-biologic intelligence[26] may be more powerful than unenhanced human intelligence, because it may "combine the pattern-recognition powers of human intelligence with the memory- and skill-sharing ability and accuracy of machines."[27] AI of 2035 may not be in the form commonly propagated in fiction. The humanoid forms of Commander Data and C3PO are unlikely. It is much more likely to find machine intelligence embedded in planes, vehicles, and task specific robots (or sitting in a rack in a computer room). These intelligent systems will use their "senses" to model their world and make predictive conclusions based on the recall of stored patterns compared to their current environment. Their intelligence will be humanlike, but their behavior

will not.[28] Ray Kurzweil doesn't predict the profound expansion of transhuman intelligence until 2045. He asserts, "The non-biological intelligence created in that year will be one billion times more powerful than all human intelligence today."[29]

Enhanced Human Intelligence –

> Humanity's ability to alter its own brain function might well shape history as powerfully as the development of metallurgy in the Iron Age, mechanization in the Industrial Revolution or genetics in the second half of the twentieth century… Our growing ability to alter brain function can be used to enhance the mental processes of normal individuals as well as to treat mental dysfunction in people who are ill. The prospect of neurocognitive enhancement raises many issues about what is safe, fair and otherwise morally acceptable.[30] -- Martha J. Farah, et al.

The second approach to improving our ability to deal with the challenge of cognition in an increasingly complex environment is to modify human intelligence through pharmacological enhancement or brain-computer interfaces. The study of cognitive neuroscience has made rapid advancements due to an increased understanding of the brain through positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). These brain scanning techniques provide a deeper understanding of the areas of the brain active during different cognitive, sensor, or motor tasks.[31] Determining the relationship between cognitive tasks and the network of brain regions identifies the nodes of the cerebral network and the associated anatomical linkages.[32] These areas can then be influenced by pharmacological or electronic stimuli.

> *Flash forward a decade and a half from today…[your daughter] has taken on her most formidable challenge yet, competing with her generation's elite in her fancy new law school.*

…
How does she explain what the enhanced kids are like?
…
They have amazing thinking abilities. They're not only faster and more creative than anybody she's ever met, but faster and more creative than anyone she's ever imagined.

They all have photographic memories and total recall. They can devour books in minutes.
…
These new friends are always connected to each other, sharing their thoughts no matter how far apart, with no apparent gear. They call it "silent messaging." It almost seems like telepathy.

They have this odd way of cocking their head in a certain way whenever they want to access information they don't already have in their own skulls—as if waiting for a delivery to arrive wirelessly. Which it does.

For a week or more they don't sleep. They joke about getting rid of their beds in their cramped dorm rooms, since they use them so rarely.

… they call her—"Natural"…They call themselves "Enhanced."[33]

Psychopharmacology represents a class of neurotechnology in which drugs are tailored to target cognition on the molecular level. This "leading edge" science primarily addresses neurological and psychological disorders, but these drugs are increasingly being used for memory and cognitive 'enhancement'. "The enhancement of normal neurocognitive function by pharmacological means is already a fact of life for many people in our society, from elementary school children to aging baby boomers." [34]

Memory enhancement is well grounded in the effort to mitigate diseases such as Alzheimer's. However, drugs like donepezil have also been used to enhance the performance of United States Army pilots (controlled study in flight simulator environment). This is an increasing trend of pharmacological companies searching for alternative uses of their drugs to enhance 'normal' people. "Recent advances in the molecular biology of memory have presented

drug designers with many entry points through which to influence the specific processes of memory formation, potentially redressing the changes that underlie both normal and pathological declines in memory."[35]

Drug companies are also finding dual-use for medications that target cognition. The enhancement of 'executive function' gives individuals the ability to focus on desired tasks and ignore irrelevant or competing stimuli. Drugs that target dopamine and noradrenaline neurotransmitter systems can relieve deficiencies in attention, working memory, and inhibitory control. The neurocognitive enhancer, modafinil, designed to help patients suffering from narcolepsy, is being used as a "go" pill for the United States Armed Forces. Modafinil, also known as Provigil, allows pilots to stay up for over 40 hours without impairment, then after eight hours of sleep, they could do it again for an additional 40 hours.[36] Methylphenidate, a drug used to combat Attention Deficit Hyperactivity Disorder (ADHD), was demonstrated to improve executive function in normal individuals. Problem solving and spatial working memory were improved. This study also indicated that individuals with lower cognitive performance would benefit more than those with higher cognitive ability. The implication is that some drugs would have a "leveling" effect, increasing the ability of the lower cognitive performer and degrading the function for higher performers.[37]

Neurocognitive enhancers brought to market as therapies for medical or psychological disorders will continue to be exploited by healthy individuals seeking enhancement to achieve a competitive advantage or recreational

reward. The research and development of neurocognitive pharmaceuticals solely for the purpose of enhancement will increase as demand increases. The associated risk-reward considerations will raise some legitimate ethical concerns. [38]

Brain-computer interfaces provide an additional method of enhancing human cognitive ability. Like pharmacological research, brain-computer interfaces are primarily developed to mitigate brain-spinal injuries or disease. These interfaces can be external devices or invasive devices that physically interact with brain tissue.

External interfaces capture and analyze brainwaves to anticipate the patient's intended action based on his mental state. The interface exploits electro-encephalitic emissions from the entire cortex to integrate sensor-motor responses. The computer can provide surrogate behaviors such as selecting icons or keystrokes, moving a robotic arm, steering a wheelchair, or enunciating words. [39] Scott Mackler adopted an external Brain Computer Interface (BCI) after ALS, Lou Gehrig's disease, left his entire body paralyzed. Scott can now "speak" via a laptop connected to his BCI. The wired cap sitting atop his head captures the electrical signals as Scott thinks of letters. The laptop converts those letters to words then sentences then to speech. [40] The future success of external brain interfaces has tremendous implication to human machine interaction that eliminates the relatively slow functions of speech or typing. Interaction could take place at the speed of thought.

Much more invasive neural prosthetics interface directly with brain tissue to stimulate or record electroneural impulses. Neural prosthetics can be used in the same way as the brainwave interface, but with greater signal strength and fidelity. DARPA's "telekinetic monkey", Belle, has an implant that allows her to control a robotic arm with her thoughts. The computer attached to the implant registers Belle's electroneural impulses from her motor cortex and moves the robotic arm just as Bell moves her own arm.[41] More recently, in January 2008, the Computational Brain Project of the Japan Science and Technology Agency moved the technology another step forward. Idoya is a rhesus monkey that has been trained to walk upright then implanted with a brain-computer interface designed to capture the neurons that control leg movement. Idoya's neuron mapping and leg movement were transferred to a robot named CB-1 (named Computational Brain). At 500 pounds and 5 feet tall, CB-1 is much larger than Idoya; yet, CB-1 is in perfect synch with Idoya.[42]

Cathy Hutchinson is among the first humans to have her brain directly wired to a computer, like Belle. Cathy volunteered to have "Braingate" implanted in her skull in hopes of regaining some freedom from being "locked in" her stroke induced prison. She can move a computer cursor with nothing other than thoughts. "She's thinking about the movement of her hand, and she's moving the cursor much as if she had her hand on a mouse." Even though she's paralyzed, when Cathy thinks of moving her arm the neurons in her motor cortex fire. Braingate captures those impulses and translates them

to cursor movements. If Cathy can control the computer, she can interact with anything attached to it.[43] These studies have implications for the physically impaired as well as the prospect of virtually controlling robots in hazardous environments or at great distances, such as on the surface of the Moon or Mars.

Neural prosthetics are also available to replace sensor organs such as cochlear implants and artificial vision. These implants interface directly with the brain but cannot provide the native neural impulses of the biologic organs. Therefore the brain must be very plastic as it "remaps to accommodate the new class of signals." [44]

While two-way communication between prosthetics and the brain are still in the proof-of-concept phase, the plasticity of the brain gives promise to enhancing prostheses that can eventually boost processing power, expand memory, provide high-speed intra-brain pathways, or enable direct computer to brain communications. A pilot, air traffic controller, or CAOC director thusly augmented and connected would possess, in effect, super-human intelligence. Someone gifted with this sort of enhanced human intelligence partnered with an AI companion could overcome the cognitive limits preventing full understanding of an increasingly complex environment.

Ethical, Moral, and Cultural Concerns

> One consideration that should be taken into account when deciding whether to promote the development of superintelligence is that if superintelligence is feasible, it will likely be developed sooner or later. Therefore, we will probably one day have to take the gamble of superintelligence no matter what. But once in existence, a superintelligence could help us reduce or eliminate other existential risks, such as the risk that advanced nanotechnology will be used by

> humans in warfare or terrorism, a serious threat to the long-term survival of intelligent life on earth. If we get to superintelligence first, we may avoid this risk from nanotechnology and many others. If, on the other hand, we get nanotechnology first, we will have to face both the risks from nanotechnology and, if these risks are survived, also the risks from superintelligence. The overall risk seems to be minimized by implementing superintelligence, with great care, as soon as possible.[45]
> -- Nick Bostrom

> This possibility [of Humanity altering its brain function] calls for an examination of the benefits and dangers of neuroscience-based technology, or 'neurotechnology', and consideration of whether, when and how society might intervene to limit its uses…This requires interdisciplinary discussion, with neuroscientists available to identify the factual assumptions that are implicit in the arguments for and against different positions, and ethicists available to articulate the fundamental moral principles that apply. As a society we are far from understanding the facts and identifying the relevant principles.[46] -- Martha J. Farah, et al.

AI and EHI both introduce risk to society. Despite the risk, these technologies must be researched and understood because some of our adversaries and competitors will continue to develop these technologies. We need to consider the implications of each specific application and make a value judgment based on value versus risk. There are four major aspects to the value-risk appraisal that should be considered for ethical, moral, and cultural propriety: Safety, Coercion, Distributed Justice, and Humanity[47].

There are two magnitudes of safety that need to be considered. The first is catastrophic risk that presents an existential risk to humanity. The manifestation of superintelligence poses the greatest existential threat, but as Nick Bostrom advocates, if superintelligence is possible then it will occur. Our best means of mitigating the risk is to build in a "super goal" of philanthropy into the core logic of the artificial intelligence.[48] Lower magnitude, non-existential threats to safety are more likely in the pursuit of AI. For AI we must

determine how much automation we are willing to accept in areas like air travel or self-defense systems. Human enhancement also carries non-existential risks. Most are typical risks of medical procedures and medicines; however, neurocognitive enhancement requires adjustment of the very complex systems in the brain which carry personality changing consequences.[49] Fortunately, superintelligence notwithstanding, the residual safety concerns are neither novel nor unique and can be dealt within existing ethical, moral, and cultural frameworks.

As AI and EHI become more prevalent there will be increasing sources of coercion as the pressure to adopt these technologies increases. For companies, there will be financial and performance incentives to implement AI in the workflow. For individuals, the ability to compete at school or on the job will drive the use of neurocognitive enhancing drugs or elective brain-computer procedures. There may, also, come a time where adoption of these technologies is compulsory. The government may direct certain control measures be implemented by 'trusted' AIs. For example, automobiles traveling on the Interstate system may be required to have an AI autopilot on board. Similarly, military service may require certain computer-brain augmentations for its members or employers in the financial sector may require use of neurocognitive drugs as a term of employment.[50] Coercive forces will drive extensive ethical and cultural debate.

Distributive justice is another area to cause friction and debate. There will be cases of the haves and have-nots within our borders and amongst

differing segments of the world population. The reproducibility of AI will increase the availability of some task specific applications. However, personal service appliances that are AI enabled may be cost prohibitive to many segments of the population. Neurocognitive enhancement is even less likely to be fairly distributed. There is already precedence for selective distribution of elective surgical procedures and medications. “Ritalin use by normal healthy people is highest among college students, an overwhelmingly middle-class and privileged segment of the population.”[51] Society will wrestle with what is determined to be a common service or entitlement. The resulting policies may do little to thwart contempt and unrest.

The most contentious debate will center on the meaning of being human. The nature of Humanity may be altered with either AI or EHI. “The fourth category of ethical issue encompasses the many ways in which neurocognitive enhancement intersects with our understanding of what it means to be a person, to be healthy and whole, to do meaningful work, and to value human life in all its imperfection.”[52] If AI meets its full potential and achieves sentience, will it be considered human? If an augmented brain has superhuman abilities is the individual still considered human? How much augmentation is permitted before a threshold is crossed? Answers to these questions are not readily forthcoming. Society will have to determine the acceptable categorization of these “individuals” and the rights to which they are entitled.

The value side of the equation is somewhat convoluted. The value of superintelligence is the promise of solving any and all world problems. "Disease, poverty, environmental destruction, unnecessary suffering of all kinds: these are things that a superintelligence equipped with advanced nanotechnology would be capable of eliminating."[53] Likewise, neurocognitive enhancement in its most advanced form could provide transhuman intelligence. Humans could become enlightened to the solutions to all of the world problems and live an exceptionally long and rewarding existence. However, it is much more likely that these capabilities will not be realized by 2035 and we will be struggling with lesser abilities in which the risk reward tradeoff is much less obvious.

Notes

[14] Moore's Law, named after integrated circuit inventor Gordon Moore, is a reference to the phenomenon that computer power doubles roughly every two years.

[15] Arbib, The Handbook of Brain Theory and Neural Networks, p. 44-47.

[16] Arbib, The Handbook of Brain Theory and Neural Networks, p. 64-65.

[17] Arbib, The Handbook of Brain Theory and Neural Networks, p. 44-47.

[18] Arbib, The Handbook of Brain Theory and Neural Networks, p. 64-65.

[19] Arbib, The Handbook of Brain Theory and Neural Networks, p. 64-65

[20] Arbib, The Handbook of Brain Theory and Neural Networks, p. 64-65

[21] Arbib, The Handbook of Brain Theory and Neural Networks, p. 40-42.

[22] Arbib, The Handbook of Brain Theory and Neural Networks, p. 77-80.

[23] Kurzweil, *Spiritual Machines.*

[24] Hawkins, *On Intelligence.*

[25] Arbib, The Handbook of Brain Theory and Neural Networks, p. 44-47.

[26] Non-biological intelligence is term used by Ray Kurzweil and others as an alternative to artificial intelligence. Artificial intelligence, once mature, will be 'real' intelligence.

[27] Kurzweil, *The Singularity is Near.*

[28] Hawkins, *On Intelligence.*

[29] Kurzweil, *The Singularity is Near.*

[30] Farah, et al., "Neurocognitive enhancement."

[31] Arbib, The Handbook of Brain Theory and Neural Networks, p. 37-39.

[32] Arbib, The Handbook of Brain Theory and Neural Networks, p. 37-39.

[33] Garreau, *Radical Evolution.*

[34] Farah, et al., "Neurocognitive enhancement."

[35] Farah, et al., "Neurocognitive enhancement."

[36] Garreau, *Radical Evolution.*

[37] Farah, et al., "Neurocognitive enhancement."

[38] Farah, et al., "Neurocognitive enhancement."

[39] Arbib, The Handbook of Brain Theory and Neural Networks, p. 77-80.

[40] CBS News, "Harnessing The Power Of The Brain."

[41] Garreau, *Radical Evolution.*

[42] Baker, "The Rise of the Cyborgs."

[43] CBS News, "Harnessing The Power Of The Brain."

[44] Arbib, The Handbook of Brain Theory and Neural Networks, p. 77-80.

[45] Bostrom, "Ethical Issues in an Advanced AI." A *superintelligence* is any intellect that is vastly outperforms the best human brains in practically every field, including scientific creativity, general wisdom, and social skills. This definition leaves open how the superintelligence is implemented – it could be in

a digital computer, an ensemble of networked computers, cultured cortical tissue, or something else.

[46] Farah, et al., "Neurocognitive enhancement."

[47] Farah, et al., "Neurocognitive enhancement."

[48] Bostrom, "Ethical Issues in an Advanced AI."

[49] Farah, et al., "Neurocognitive enhancement."

[50] Farah, et al., "Neurocognitive enhancement."

[51] Farah, et al., "Neurocognitive enhancement."

[52] Farah, et al., "Neurocognitive enhancement."

[53] Bostrom, "Ethical Issues in an Advanced AI."

Chapter 4

Cognitive Superiority -- A smarter Air Force in 2035

> Technology is ***likely*** (emphasis included) to produce breakthrough events at an unprecedented rate in the period out to 2035…While it ***will*** be difficult to predict particular breakthroughs, trend analysis indicates that the most substantial technological developments ***will*** be in: ICT [Information Communication Technology], biotechnology, energy, cognitive science, smart materials and sensor/network technology…where disciplines interact, such as in the combination of Cognitive Science and ICT to produce advanced decision-support tools, developments are ***likely*** to be revolutionary, resulting in the greatest opportunities for novel or decisive application.[54]
> – "Strategic Trends", Development, Concepts and Doctrine Centre, UK MOD

The future environment of 2035 is impossible to predict with today's cognitive resources. However, it is certain that it will be a dynamic, rapidly changing environment. This environment will require adaptability and flexibility of smart, autonomous and human systems driven by the cognitive technologies of AI and EHI.

The Blue Horizons II[55] study was tasked to "develop a prioritized list of concepts and their key enabling technologies that the United States Air Force will need to maintain the dominant air, space and cyber forces in the future." The study created four possible futures (Jihadist Insurgency, Failed State, Resurgent Russia, and Peer China) as analytic environments to evaluate required military capabilities needed in the year 2030. The Blue Horizons II study proposed that decision making would need to be at machine speeds. "Time between observation and action in tactical engagements will be measured in fractions of seconds." The current human-in-the-loop model in which the human makes decisions, turns the key, pushed the button, or pulls the trigger, will be inadequate in the future. Instead "machines will execute

human *intent* (emphasis added) at machine speeds." In the future, humans will remain "in-the-loop" through expressing their will and through creating, repairing, and analyzing machines.[56] There will likely be some exceptions to this scenario where humans must be left in the loop, such as the employment of nuclear weapons. 'Enhanced' humans may also continue to play a more active role in engagements of the future. However, the majority of operations will be largely automated.

Figure 4 - Blue Horizons II (2008) Ranked Order of Concepts[57]

The result of the Blue Horizons II study prioritized 58 relevant concepts (Figure 4) across all four possible 2030 futures. These concepts are enabled by 172 technologies currently in various stages of maturity. One of the striking outcomes of the Blue Horizons II study is that the concept scores are

remarkably consistent across the four futures. The implication is that the Air Force capabilities required for each future are similar and the “Air Force mission sets remain constant across a variety of scenarios.” The study also demonstrated that the capabilities required for communications, cyberspace, sensing, attribution, and data fusion were almost identical in all scenarios. [58]

Figure 5 - Blue Horizons II - Top Ten Concepts[59]

The top ten concepts (Figure 5) all require a high degree of autonomy, pattern recognition, data fusion or decision support. These capabilities highlight the increased role for unmanned platforms and the increased need to navigate, explore, defend, and attribute attack in cyberspace. In particular the top two concepts (Wingman and Cybercraft) will require a fairly advanced artificial intelligence capability (and may support a direct brain interface to human operators and decision makers.) The Wingman concept is an

Unmanned Combat Air Vehicle capable of multi-spectral sensors fusion for target identification and threat detection, in-flight self diagnostics and repair, control of swarms of micro-vehicles, and control of engagements through battle management systems. The Cybercraft concept is a virtual platform capable of 'moving' through cyberspace. The Cybercraft will be capable of sensing, identifying, reporting, and engaging threats or targets in cyberspace.[60] Not only are these the two highest ranked concepts, they also require almost twenty-five percent of the enabling technologies. The study shows that many of the other concepts are also dependent on cognitive technologies. This serves as an indication of the importance of cognitive technologies that are required to support Air Force operations in 2035.

Enabling Technology Category	# Technologies
Assured Communications	4
Auto Track/Sense	9
Vehicle Self Defense	8
Assured Navigation	12
Cyber Protect/Attack	17
Data Fusion/Analysis	6
Laser Optics/Beam Technologies	8
Engine Technologies	7
UAV C2	4
Structures & Materials	4
Space Launch/Ops/Forecast	6
Nuclear Cleanup (supports UAV)	1
Power Generation/Storage	3
High Speed Weapons	3

Figure 6 - Blue Horizons II - Prioritized Technologies[61]

The need for the enhanced cognitive capabilities is also reflected in the top technology categories in the Blue Horizons II (Figure 6). These technologies indicate the high degree of machine autonomy and situational awareness required for Air Force operations in 2035. One of the harsh realities revealed by the study is that humans will no longer play a significant role in crises management, but will be required to put more emphasis in ability to anticipate, defuse, and mitigate crises. Both sides of this reality require enhanced cognitive capabilities through AI and EHI. Additionally, all of the key technologies required for or supported by enhanced cognitive capabilities are led by the Department of Defense or have shared leadership by the Department of Defense and other government agencies (Figure 7). [62]

High Leverage Technology	DOD Lead	DOD & U.S. Govt	U.S. Govt and Industry	Industry Lead
Assured Comm.		X →	→	→
Auto Tracking/Sensing	X			
Vehicle Self Defense	X			
Assured Navigation		X →	→	
Cyber Protection	X →	→	→	
Data Fusion/Analysis		X →	→	→
Lasers/Optics	X →	→		
Engine Technologies		X →	→	→
UAV C2		X		
Structures and Materials		X →	→	→
Space Launch/Ops			X →	→
Nuclear Clean-up			X	
Power Generation/Storage			X →	→
High Speed Weapons	X			

Figure 7 - Blue Horizons II - Tech Development Leadership[63]

The need for improved understanding and prediction of the battlespace is also advocated by the Air Force Scientific Advisory Board's Predictive Battlespace Awareness study[64]. This study, published in 2002, asserts that "[Predictive Battlespace Awareness] is a necessary enabler of all AF Task Forces." The Scientific Advisory Board emphasizes that pre-conflict predictive capabilities are essential to the "commander's knowledge of the possible future antagonists in the assigned area of responsibility along with their cultural biases, political and military perspectives, doctrine, strategic and tactical goals, forces, potential courses of action, possible tactical approaches, and other factors which will be needed in the event of conflict."[65] The level of prediction required to form "a multidimensional understanding of the battlespace in time, space, and effect, regardless of the adversary, location, weather, or time of day" is not possible without the cognitive assistance of AI or EHI. [66]

Our allies in the United Kingdom have come to similar conclusions about the need and availability of cognitive technologies in the 2035 time-frame. "Strategic Trends," a study published in 2007 by Development, Concepts and Doctrine Centre, a Directorate General within the UK's Ministry of Defense, recognizes the acceleration of technological change and its impact on global society. Some of the key predictions in the "Strategic Trends" study are as follows[67]:

> **Knowledge and Innovation**: The rate of change, tempo and unpredictability of innovation and development ***will*** challenge decision-makers who ***will*** have to anticipate and respond to direct and indirect outcomes. Notwithstanding this, trends indicate that the most rapid technological advances are ***likely*** in: Information Communications Technology (ICT), energy, biotechnology, cognitive science, sensors and networks and smart materials. Nanotechnology is ***likely***

> to be an important enabler for other developments, for example in electronics, sensors and commodity manufacture.
>
> **Biotechnology:** Quality of life ***will*** also improve through, for example, the development of…memory enhancing drugs, development of artificial sensors capable of interfacing with the human mind and prosthetics capable of mimicking human actions precisely, improving human performance beyond current levels.
>
> **Cognitive Science:** Routes to the direct application of advances in cognitive science are less clear than nanotechnology or biotechnology; however, indications are that interdisciplinary advances involving cognitive science are ***likely*** to enable us more effectively to map cognitive processes. Soft Artificial Intelligence is already well established with self diagnosing and self reconfiguring networks in use and self repairing networks ***likely*** in the next 10 years. Mapping of human brain functions and the replication of genuine intelligence is ***possible*** before 2035.
>
> **The Role of Artificial Intelligence**: The simulation of cognitive processes using Artificial Intelligence (AI) is ***likely*** to be employed to manage knowledge and support decision-making, with applications across government and commercial sectors. Reliance on AI ***will*** create new vulnerabilities that are ***likely*** be exploited by criminals, terrorists or other opponents.
>
> **Broadcasts to the Brain**: By 2035, an implantable information chip could be developed and wired directly to the user's brain. Information and entertainment choices would be accessible through cognition and might include synthetic sensory perception beamed direct to the user's senses. Wider related ICT developments might include the invention of synthetic telepathy, including mind-to-mind or telepathic dialogue. This type of development would have obvious military and security, as well as control, legal and ethical, implications.

The technologies and capabilities discussed thus far do not define the future. They serve as examples of what *can* be; not necessarily what *will* be. Many of the technologies being researched today will not reach the level of maturity needed to produce the miracles necessary for artificial intelligence and enhanced human intelligence. For example, the "Broadcasts to the Brain" segment is found in the "Strategic Shocks" section of the "Strategic Trends" study. While possible, the authors of the "Strategic Trends" study did not expect the capability to be available by 2035. Many of the technologies discussed in this paper may not reach fruition, but these are not the only

paths to success to mature cognitive technologies. The accelerating advances in basic nano-bio-info technologies give near limitless opportunities for development as well as application of cognitive technologies.

Although most of the literature available discusses the application of cognitive technologies on operational or tactical engagements, it is reasonable to extend these technologies and capabilities into the strategic domain. A better understanding of the strategic environment can shape force development decisions in terms of research, acquisitions, training, manpower levels, etc. Furthermore, cognitive dominance could provide a strategic advantage with respect to determining adversary capabilities and intent. AI and EHI can be brought to bear on all levels of leadership and engagement.

Notes

54 UK MOD DCDC, "*Global Strategic Trends.*" The "Strategic Trends" study provides predictions about the future context for the military for approximately 30 years into the future. These predictions are issued with a degree of confidence related to their probability. Events or technologies that ***will*** occur have a confidence of near certainty have a probability of >95%. Those that are characterized as ***likely*** have a high confidence and a probability of >60%. .

55 Blue Horizons is a group of Air War College (AWC) students selected to support the research requirements of the Center for Strategy and Technology (CSAT). CSAT was established at the Air War College in 1996. Its purpose is to engage in long-term strategic thinking about technology and its implications for U.S. national security. Blue Horizons II was comprised of AWC students in academic year 2008. More information on CSAT and Blue Horizons can be found at http://csat.au.af.mil/.

56 AWC BH II, 2008 Final Report Briefing to Air University Commander

57 Reprinted from AWC BH II, 2008 Final Report Briefing to Air University Commander

[58] AWC BH II, 2008 Final Report Briefing to Air University Commander

[59] Reprinted from AWC BH II, 2008 Final Report Briefing to Air University Commander

[60] AWC BH II, 2008 Final Report Briefing to Air University Commander

[61] Reprinted from AWC BH II, 2008 Final Report Briefing to Air University Commander

[62] AWC BH II, 2008 Final Report Briefing to Air University Commander

[63] Reprinted from AWC BH II, 2008 Final Report Briefing to Air University Commander

[64] AF SAB, Briefing on PBA

[65] AF SAB, Briefing on PBA

[66] AF SAB, Briefing on PBA

[67] UK MOD DCDC, "*Global Strategic Trends*"

Chapter 5

Recommendations

Cognitive technologies will be part of the strategic landscape through 2035. These technologies will be advanced with or without Air Force involvement. However, it is in the best interest of the Air Force to be fully engaged in the development of cognitive technologies. There are three simple recommendations that can guide the Air Force engagement strategy with respect to AI and EHI.

Recommendation 1

Accept and embrace the legitimacy of cognitive technologies and their value to the Air Force. Acknowledgement will require consideration of the moral and ethical concerns associated with AI and EHI.

Recommendation 2

Support cognitive research and development. Cognitive technologies are fundamental to many of the capabilities required in 2035. The Department of Defense either has the lead or shares the lead on the enabling technologies pertinent to advanced cognition. The cognitive requirements for highly autonomous systems, cyber operations, and Predictive Battlespace Awareness demand that the Air Force assume or maintain a leadership role in the development of these technologies.

Recommendation 3

Use spiral approach to cognitive systems. Deploy capabilities as soon as they reach maturity. Don't wait for the perfectly integrated or developed system. Cognitive technologies, by their nature will help develop the next spiral. Furthermore, there is significant opportunity for spin-off capabilities with each spiral.

Chapter 6

Conclusion

> The benefit of strategic futures work is not that it predicts the future, which is unpredictable, or enables organizations to control it. It is about rehearsing possibilities, so one is better able to respond if they happen. [68]
>
> -- Benchmarking UK Strategic Futures Work
> – Government Performance and Innovation Unit

> All this to say future enemies will be ***motivated*** by resources, fear, and hate; ***empowered*** through education; and ***enabled*** through technology and globalization to directly challenge the US. The ***enemy*** will be different -- the targets they present will be more ***difficult*** to find, ***harder*** to hit, more widely ***distributed***, and more ***dangerous.*** [69]
>
> -- The New Battlespace defined by Blue Horizons II Study

There is widespread acknowledgement that the rate of change will continue to increase and that "during the next 30 years, every aspect of human life ***will*** change at an unprecedented rate, throwing up new features, challenges and opportunities."[70] It is impossible to anticipate the exact nature of these changes or predict the future with any degree of certainty. The only certainty is that there will be change.

The human inability to fully comprehend the non-linear nature of the change exacerbates the challenge of shaping the future and executing the Air Force mission to Fly, Fight, and Win in Air, Space, and Cyberspace. Any measure of success in the highly complex environment of 2035 will require cognitive technologies driving the intelligence behind autonomous systems, decision support systems, and the human mind.

The research supporting the required capabilities in AI and EHI are in various levels of maturity. While most of the research is fairly immature, the convergence of nano-, bio-, and info- technologies promises to yield

breakthroughs in cognitive technology research. Furthermore, the nature of the Cognitive-Nano-Bio-Info positive feedback loop will serve to accelerate cognitive technology development.

The pursuit of cognitive technologies is not without obstacles and hazards. There are many ethical and moral implications with both AI and EHI. The development of transhuman intelligence is not likely by 2035, however the implications of an artificial entity that has the potential to be omnipotent and omnipresent must be considered when working to develop any general artificial intelligence. The implications of altering the human brain through psychopharmacology or surgical implants must also be considered as the fundamental question of what it means to be human will be challenged with augmented superhuman intelligence.

Despite the potential pitfalls of cognitive technologies, they must be pursued; where we would seek constraint, our adversaries would seek advantage. Furthermore, the capabilities cognitive technologies provide are critical to the mission of the Air Force in 2035. Almost all of the 2030 technological concepts identified by Blue Horizons II require highly autonomous systems capable of navigation, target recognition and self-defense; they require predictive battlespace awareness capable of data fusion and an understanding of the future environment; or they require cyber dominance with assured communications and freedom of action in the cyber domain. Many require a combination of these capabilities, such as the top two concepts, the Wingman Unmanned Combat Air Vehicle and the Cybercraft AI Entity.

These concepts and their enabling technologies are directly supported by cognitive technologies.

Department of Defense has a principal role in the development of cognitive dependent technologies and the Air Force will have a critical reliance on cognitive technologies. Therefore the Air Force must 1) recognize the legitimacy of the cognitive technologies and should take steps to 2) invest in cognitive technology research and develop and 3) adopt a spiral approach to fielding cognitive technologies to maximize usefulness.

Notes

[68] Quoted in UK MOD DCDC, "*Global Strategic Trends*"

[69] AWC BH II, 2008 Final Report Briefing to Air University Commander

[70] UK MOD DCDC, "*Global Strategic Trends*"

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